JOURNAL OF
Creative Behavior
Publication of the Creative Education Foundation™

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How to Guard Against Fixation? Demonstrating Individual Vulnerability is More Effective Than Warning of General Risk

ABSTRACT

Creative behavior can be inhibited by fixation and so reducing fixation is a focus of much creativity research. One of the most common methods of tackling fixation is to warn people of fixation risks and instruct them to avoid constrained problem framing and solution search. However, such treatments are often ineffective. One possible explanation for this is that people typically believe that they (as individuals) are less vulnerable to a specified risk than other people are (in general). If we really want to motivate people to guard against a risk, we need to demonstrate that they, as individuals, are vulnerable to those risks. To study the effect of demonstrating individual vulnerability to fixation, we conducted an online experimental study using number and word tasks that both included a fixation "trap." The first task was used to provide a "demonstrated vulnerability" treatment (revealing participants' own fixated behavior) to the experimental group. This group outperformed those who received a comparable "asserted vulnerability" treatment (a warning about general fixation effects) and also those in a control group. Researchers and practitioners developing creativity training and tools aimed at reducing fixation effects should consider the benefits of demonstrating individual vulnerability to fixation rather than, or in combination with, issuing warnings that people in general are vulnerable to fixation.

Keywords: fixation, creativity, problem-solving, demonstrated vulnerability.

INTRODUCTION

Despite its recognized importance, creativity is often difficult to achieve, with people inadvertently focusing on a narrow interpretation of the problem, a narrow range of solutions, or a narrow set of problem-solving processes. Collectively, these unnecessary and inadvertent restrictions are termed "fixation," which refers to the variety of mental blocks that can impede insight, often resulting from the counterproductive effects of prior knowledge (Smith, 1995).

One approach to reduce fixation in problem-solving is to give warnings about it: warnings about the prevalence and effects of fixation. However, this method has often been found to be ineffective. One possible reason for this may be that individuals believe themselves to not be at risk of fixation even if they believe such risks apply to people more generally. For example, in the domain of health care, it has been shown that "merely pointing out" an individual's vulnerability to a certain risk is seldom an effective way to motivate that individual to reduce that risk (Aiken, Gerend, & Jackson, 2001; Curry, Taplin, Anderman, Barlow, & McBride, 1993). In the context of cognitive bias research, individuals are known to recognize the existence and operation of such biases in other people more so than they do in themselves (Pronin, Lin, & Ross, 2002). This "bias blind spot" does not appear to be attenuated by increased cognitive abilities (West, Meserve, & Stanovich, 2012), perhaps because people believe that their own (but not others') capacity for introspection is a means to address bias (Pronin & Kugler, 2007). It seems that even if someone recognizes that a group they belong to is susceptible to risk, they are liable to underestimate or discount their own individual susceptibility (Aiken et al., 2001; Weinstein, 1980).

If people tend to overlook, disregard, or downplay their own individual vulnerability to risk or bias, then warning them about fixation might be expected to have limited or unreliable effects. An alternative approach would be to *demonstrate* that vulnerability at an individual level. Such an approach has been used for many years through the application of the implicit association test to raise people's awareness of their own biases (Devine et al., 2012). It has also been shown to be effective in developing people's resistance to persuasion tactics, where those in an "demonstrated vulnerability" treatment outperformed those in an "asserted vulnerability" treatment (Sagarin, Cialdini, Rice, & Serna, 2002). Could the same thing work for creative problem-solving? In the present study, we sought to find out. We hypothesized that providing people with experiences that demonstrate their individual vulnerability would give rise to a significantly stronger tendency to resist later fixation episodes, in comparison with simply asserting that people in general are vulnerable to fixation. By testing this hypothesis, we aimed to provide knowledge about how we might reduce fixation effects and therefore suggest ways in which we might encourage or support creativity.

LITERATURE REVIEW

FIXATION AND METHODS OF PREVENTION

In the field of cognitive psychology, researchers have clarified the obstacles that most people are likely to face in creative situations (Kohn & Smith, 2011; Smith, 1995). In particular, a number of studies have shown how activated knowledge can constrain the ability to generate novel ideas. For example, creative problem-solving can be inhibited when the solution requires people to generate an atypical object function after the object's typical function has been primed (Adamson, 1952; Duncker & Lees, 1945). Similarly, people can struggle in finding novel approaches to solve problems after becoming familiar with a particular set of problem-solving approaches (e.g., Luchins, 1942; Neroni, Vasconcelos, & Crilly, 2017). In more open-ended tasks, the first ideas that people consider during creative idea generation can constrain the ideas that they subsequently generate, whether those initial ideas were provided at the outset or generated during the tasks (Neroni & Crilly, 2019; Smith, 1995). (For reviews and overviews of such research, see Sio, Kotovsky, & Cagan, 2015; Vasconcelos & Crilly, 2016.)

Various methods have been identified to tackle the causes and consequences of fixation effects. One common approach is providing people with explicit instructions (e.g., warnings) aimed at avoiding the automatic repetition of inappropriate behaviors. However, the results of experimental studies using this approach are mixed. Some results are positive, such as Luchins' (1942) seminal work on the Einstellung effect (i.e., a fixating effect resulting from people's previous experience with a particular approach to solving problems). Luchins found that giving the instruction "don't be blind" to some of his experimental groups reduced the occurrence of the Einstellung effect by about 55 percent. Chrysikou and Weisberg (2005) also found that using defixation instructions (i.e., explicitly asking people to avoid using negative features from previously provided example solutions) eliminated the fixating effect of the example solutions in problem-solving (see also Yilmaz, Seifert, & Gonzalez, 2010). In addition to instructing people to disregard solution features, participants might be warned about fixation with the expectation that their subsequent creative performance will be improved. For example, in Lane and Jensen's (1993) experiment, one group was provided with text that said: "Hint for Solution. Under some circumstances, people who have developed a strategy to solve a series of problems are less likely to solve a subsequent problem. The subsequent problem, presented alone, is solved very easily." Participants receiving this hint were three times more likely to solve the subsequent problem than were subjects in the other experimental conditions. Such warnings were expanded upon by Howard, Maier, Onarheim and Friis-Olivarius (2013) who report that educating design students on fixation reduced its constraining effect in subsequent problem-solving, enabling the students to effectively devise their own strategies to avoid or overcome fixation (also see Onarheim & Friis-Olivarius, 2013).

While some researchers have found that warning about fixation is effective in reducing its occurrence, the opposite is also true. For example, Jansson and Smith (1991) did not find fixation to decrease when participants were instructed to avoid using specific problematic features from example solutions to open-ended problems. Perttula and Sipilä (2007) also clearly instructed participants not to reproduce the examples given in a creative task and arrived at similar negative results (also see Vasconcelos, Neroni & Crilly, 2018). However, perhaps most relevant to our interests here is the study by Smith, Ward and Schumacher (1993, Experiment 3) who go further, warning one group of participants "We have found that examples like those you examined restrict people's creativity. Try NOT to restrict your ideas" (p. 843). They still found that this did not reduce the conformity effect observed in other groups who received no such warning. The same wording was used by Martini (2018, Experiment 1) to condition one of her experimental groups, with another group told "Keep in mind that people have a tendency to unconsciously copy example features into their own designs. Try your best to avoid this common mistake." When the performance of these two groups was compared with other groups who were provided with instructions which instead focused on ways to approach the task, her results showed no clear difference between the groups. Even Luchins' results to the "don't be blind" intervention are not so straightforward as they might at first appear, with his qualitative data revealing that different participants interpreted and reacted to this warning in different ways.

It seems that merely warning people about the risks of fixation is not a reliable way of motivating them to act against it (Perloff, 1987). As Mileti et al. (2004) state in their recommendations for how to communicate and educate people about public hazards, to concretely act against a risk, people must be convinced that that risk applies to them. This is a challenge when tackling fixation because people are not aware of it when it is occurring (e.g., Marsh, Ward, & Landau, 1999; Perttula & Liikkanen, 2006; Youmans & Arciszewski, 2014). In experiments, participants might even report that the fixating example is having a positive effect on their idea generation (Linsey, Tseng, Fu, Cagan, Wood, & Schunn, 2010). However, this does not mean that people cannot become conscious of previous episodes in which they have been fixated, but recognize the costs of those fixations and the risk that they might become fixated again in the future.

THE EFFECT OF PERSONAL EXPERIENCE

Empirical research from a wide range of research disciplines has demonstrated that learning based on first-hand experience is more powerful in motivating future behavior than that based on general information (e.g., Aiken, Gerend, & Jackson, 2001; Bilalić, McLeod & Gobet, 2008; Weinstein, 1989). Much of this work is inspired by research in the branch of health psychology, which studies the "optimistic bias" (Weinstein, 1980): the discrepancy between an individual's perceptions of other people's susceptibility to a disease and their own susceptibility to that same disease. This can lead to negative health outcomes, as low levels of perceived personal susceptibility are associated with poor compliance with preventative health behaviors (Aiken et al., 2001). However, more general research in the field of perceived risks shows that the optimistic bias can be moderated by a person's level of prior personal experience with the risk factor (e.g., Helweg-Larsen, 1999; Norris, Smith, & Kaniasty, 1999; Van der Velde et al., 1992; Weinstein, 1980). Such work demonstrates that personal experience with a negative event—including earthquakes, hurricanes, illnesses, and sexually transmitted diseases—has the capacity to undercut one's illusion of unique invulnerability regarding future such events (for a review, see Weinstein, 1989).

If we look to those disciplines that focus on creative problem-solving, we find suggestions that the experience of fixation (and its negative consequences) is a means by which experts reflect on their biases and learn to resist them. For example, Bilalić, McLeod and Gobet's (2008) study on chess experts showed that moderate levels of expertise did not prevent fixation on known (but inferior) solutions, but very high levels of expertise did. Commenting on their study, the authors propose that "Actively remembering that you are susceptible to the Einstellung effect is [one] way to counteract it. […] We must try and learn to accept our errors if we sincerely want to improve our ideas" (Bilalić & McLeod, 2014, p. 79). Moving from laboratory studies to field studies, Crilly's (2015) interviews with professional designers suggest something similar. The experts described themselves as not just fixation-aware, but as fixation-averse. This aversion was derived from reflecting on prior personal experiences of their own fixation, reflections which they used to identify new fixation risks and to implement countermeasures (Crilly, 2015, pp. 74–75; also see Cross and Clayburn Cross (1996, p. 98). Metacognition in creativity is well discussed already (Armbruster, 1989; Feldhusen, 1995), but this focus on identifying, recalling, and anticipating fixation is new.

Of course, the idea that reflecting on experience might improve performance is not new. In the field of education, John Dewey (1933) long ago claimed that "we do not learn from experience… we learn from reflecting on experience" (p. 78). Following Dewey, Schon's influential book *The reflective practitioner* (1983) focused on activities in which professionals become aware of their implicit knowledge base and learn from their experience. This concept of reflective practice has been influential among those seeking to improve creative performance, especially in educational settings (Ishii & Miwa, 2005; Ringel, 2003). Reflective practice is also increasingly applied in medical contexts to raise awareness about and reduce the effects of bias (Mann, Gordon, & MacLeod, 2009; Teal et al., 2010; Thompson & Pascal, 2012). An important trigger for such reflection is the initiation of cognitive dissonance (Aronson & Carlsmith, 1968), a social psychology concept where a person becomes aware of two conflicting cognitions or ideas. This dissonance can draw attention to discrepancies between beliefs and behavior (Stone & Cooper, 2001), such as the chasm between the belief that one is unbiased, and behavioral evidence to the contrary (see earlier discussion of "the bias blind spot"). Cognitive dissonance has been found to stimulate reflection (McFalls &

Cobb-Roberts, 2001; Thompson & Pascal, 2012), shift attitudes (Gringart, Helmes & Speelman, 2008), and even change behavior (Dickerson et al., 1992).

DEMONSTRATING VULNERABILITY TO BIAS

There is both theory and evidence from a variety of disciplines, which suggest that when people experience their own susceptibility to a bias, this might alter their future susceptibility to that bias by motivating them to guard against it or try to counteract it. However, as previously discussed, such experiences might take years to develop and a high level of self-awareness to recognize, recall, and process the relevant episodes effectively. If we are to tackle fixation, there are questions about how we might develop the opportunities to acquire the relevant experiences and promote the necessary reflections. In looking for answers, there are two useful bodies of prior work: (a) literature on the effect of revealing individual's unconscious social biases with the "Implicit Association Test," and (b) literature on the effect of revealing individual's susceptibility to persuasion methods with a "demonstrated vulnerability" treatment.

The "Implicit Association Test" (IAT) is a set of computer-based trials that were developed with the objective of revealing implicit biases in various matters of social cognition (most famously biases related to race, age, and gender) (Greenwald, McGhee, & Schwartz, 1998). An important feature of the IAT is its widely reported ability to reveal biases that might be unintentional, unknown, underestimated, denied, or otherwise hidden by the participants (Greenwald et al., 2002; Greenwald et al., 1998). Because of this, it has been used for many years to reveal people's biases to them in a way that raises their awareness of the bias, their concern for its effects, and their motivation to adopt strategies to address it (Devine et al., 2012). The IAT has provided a platform for developing "unconscious bias training programs" aimed at adjusting automatic patterns of thinking and reducing discriminatory behaviors through people's exposure (and subsequently reflection) on their own unconscious biases (e.g., Hannah & Carpenter-Song, 2013; van Ryn et al., 2015). One way of framing this approach is that people are having their individual vulnerability to social bias demonstrated to them so that they can reflect on that bias and guard against it in the future.

Although the IAT is widely used, the idea of "demonstrated vulnerability" is most explicit in Sagarin et al.'s (2002) work examining the effect of a treatment in which experimental participants are shown that they (as individuals) are susceptible to deception rather than just being told that they are (or that people are in general). This treatment was introduced in a study of how deceptive persuasive messages can be resisted. Sagarin et al. (2002, Experiment 3) compared the behavior of different experimental groups, including those given an "asserted vulnerability" treatment (asked to reflect on the possibility that they had been fooled by an unethical advert) and those given a "demonstrated vulnerability treatment" (provided with evidence that they had been fooled by an unethical advert). When those participants responded to subsequent adverts, it was found that the asserted vulnerability treatment was not enough, participants had to have their vulnerability demonstrated for an effective resistance to be developed. A similar approach has been taken in alerting people to the risks of hackers using social engineering attacks to gain access to otherwise-secure computer networks (for a discussion, see Scheeres, 2008). Organisations work to combat this during corporate training sessions by making covert attacks against trainees and then revealing the results to demonstrate individual trainees' susceptibility to such attacks (Sagarin & Mitnick, 2012: pp. 35–36).

Can something like the IAT or a demonstrated vulnerability treatment be developed to provide an immediate demonstration of an individual's susceptibility to fixation? Could such an intervention act to accelerate that individual's opportunity to reflect on such susceptibility and then guard against it when confronted with future creative challenges? Answering these questions could point the way to offering a practical and efficient method of decreasing fixation effects and thereby enhancing creativity.

THE PRESENT STUDY

In the present study, we sought to develop and test the efficacy of a "demonstrated vulnerability" intervention for fixation. We adopted the general experimental structure of Sagarin et al.'s (2002) study, with three groups: demonstrated vulnerability, asserted vulnerability, and control. We used two fixation tasks: For our conditioning of the independent variable, we used a number task (Luchins' (1942) three jars task); and for measuring the effect on our dependent variable, we used a word task (Cowen and Thompson's (1951) alphabet maze task). The demonstrated vulnerability group completed the three jars task and were given feedback on their fixated behavior. The asserted vulnerability group were told about studies conducted with the three jars task and were informed about people's susceptibility to fixation. The control group were given an arithmetic task based on the three jars study. Following these tasks, all the groups completed the alphabet maze task.

We chose Luchins' three jars task to demonstrate and explain fixation because it provides an immediate, domain-neutral, and objective indication of a person's susceptibility to fixation in problem-solving (features that are not available with open-ended tasks, such as those based on Jansson and Smith's (1991) design activities). The task consists of a series of problems requiring participants to use three jars, each with a specified capacity, to measure out the required volume of liquid. Initial "practice" problems are solvable by the same complex method, but in later "critical" problems, an alternative simpler method is also possible. In these last problems, experience is said to comprise a "trap," which may result in overlooking the simple method. Cowen and Thompson's alphabet maze task is superficially different but structurally similar (for an analysis, see Cowen et al., 1953).

We hypothesized that experiencing the "demonstrated vulnerability" intervention with the three jars task would make participants in that group more resistant to fixation in the later alphabet maze task compared with participants in the asserted vulnerability group (who had only been warned about the risk of fixation) and in the control group (who had not previously received any intervention related to fixation).

METHOD

PARTICIPANTS

One-hundred and sixty-eight participants (30 female) were recruited into the study by responding to a posted advertisement published on the online platform Amazon Mechanical Turk (for methodological considerations, see Highhouse & Zhang, 2015). We restricted the recruitment to participants who were native English speakers, aged between 18 and 30 years, and studying at university. Their average age was 26.42 years ($SD = 3.39$). Most of the participants had a bachelor's degree (60.55%) as their highest qualification, followed by those having some college qualification but not a degree (17.43%) and those having a graduate degree (11%). Only a few participants had an associate degree (5.5%) or a high school diploma (5.5%) as their highest qualification. Participants were studying various disciplines, including engineering, computer science, languages, psychology, accounting, economics, biology, arts, politics, mathematics, and journalism.

Before starting the study, participants read an on-screen information sheet and gave their consent to participate. Participants received a small honorarium (5 USD) in return for their participation. The study procedures were approved by the local ethical review committee.

MATERIALS AND PROCEDURE

At the beginning of the study, participants were randomly assigned to one of three experimental groups: demonstrated vulnerability, asserted vulnerability, and control. Participants in all groups were individually involved in two sessions: The tasks in Session 1 varied according to the experimental group; and the tasks in Session 2 were common to all the groups. For both sessions and all the tasks, the instructions were presented on a computer and all activities were conducted on a computer.

Each participant accessed the study by entering the Amazon Mechanical Turk platform and then following a link leading to the Qualtrics survey software. An initial introduction explained to the participants that they would complete a series of tasks involving numbers and letters and answer some questions. Then, participants were introduced to Session 1.

For the demonstrated vulnerability group, Session 1 included a computerized version of the three jars task. This was adapted from Bugelski and Huff's (1961) revised version of Luchins' (1942) original task. In each problem, participants viewed images of three jars marked "A," "B," and "C" with numbers indicating their capacities, and a target vessel with a number indicating the volume of liquid that should be transferred into it. The capacities of the three jars and the required target volume varied across problems.

The task included two sets of problems: five "set problems" that could all be solved by the same complex sequence of pouring operations (i.e., B–A–2C) and one "test problem" that could be solved using the same method but a simpler (and easier) solution was also possible (i.e., A + C) (see Table 1). For each problem, participants were required to find the simplest solution (i.e., the one that required the fewest pouring operations).

To ensure the participants had correctly understood the instructions and were able to complete the task properly, they were then given a "practice problem" whose solution was different from the one required to solve both the "set problems" and the "test problem" (i.e., "C–2A–B"). This avoided the possibility that

TABLE 1. Set Problems and Test Problem in the Three Jars Task. For Each Problem, Participants were Asked to Identify the Simplest Way to Measure out the TARGET Volume

	Jar A	Jar B	Jar C	TARGET
Practice problem	11	8	65	35
Set problem 1	25	59	2	30
Set problem 2	32	69	3	31
Set problem 3	52	78	3	20
Set problem 4	43	93	4	42
Set problem 5	31	61	4	22
Test problem	13	35	3	16

participants might consider that they were "instructed" to apply the formula used in the "practice problem" to solve the following problems. Participants were allowed to start with the task only if they had been able to solve the "practice problem" (there was no time limit for this). During the task, participants were given a maximum of two-and-a-half minutes to solve each problem. After typing their response (in the corresponding text box located underneath the picture illustrating the problem), participants could move from one problem to the next one by pressing a button.

Following the completion of the three jars task, participants were invited to examine their response to the "test problem" and asked whether or not this response indicated that they had noticed the alternative, simpler solution. Depending on their response to this question, participants were given a slightly different explanation of fixation: Participants who had been unable to find the simpler solution to the "test problem" (which was expected to be the majority) were informed about the possibility of this alternative solution and were told that their inability to find it when working on that problem was probably due to a "fixation effect"; participants who had been able to find the simpler solution to the "test problem" were congratulated on their performance and informed that many people are unable to identify the alternative, simpler solution due to a "fixation effect." Following this individual feedback, all the participants were provided with a deeper explanation of fixation and were given some examples of real-life fixation behaviors (see the Appendix S1 for the full texts). Finally, participants were invited to keep in mind what they had learnt in Session 1 when working on the following tasks.

For the asserted vulnerability group, Session 1 included an online lecture on "fixation." Specifically, participants were required to read text that (a) introduced the concept of fixation, (b) described the "three jars task" as an example of a task used in scientific studies on fixation alongside some typical results obtained in those studies, and (c) provided some examples of real-life fixation behaviors (see the Appendix S1 for the full text). To ensure that participants had carefully read the text and understood the concept of fixation, their knowledge was then tested with a set of five multiple-choice questions. The amount and type of information about fixation that participants in this group received (in the text) was the same as in the demonstrated vulnerability group (i.e., the same task was used to introduce and explain the concept of fixation, using the same number and same type of fixation examples). However, in the demonstrated vulnerability group, the participants completed the three jars task and were then introduced to the concept of fixation by reviewing and reflecting on their previous performance in that task. In the asserted vulnerability group, the participants were presented with the three jars task as an example of the tasks used to research fixation and they received an explanation of the typical "fixation" behavior observed in this task. Before reading the text, participants were invited to read it carefully as they would later be asked to answer some questions about its content. (This was to ensure attention and comprehension in this condition and balance the timing between the conditions.) There was no time limit for participants to read the text or answer the questions. If participants answered the questions incorrectly, they were informed of this and allowed to try again until the correct answers were given. They were allowed to move to Session 2 only if they had answered all the questions correctly. Finally, participants were invited to keep in mind what they had learnt in Session 1 when working on the following tasks (just as with the demonstrated vulnerability group).

For the control group, Session 1 included an arithmetic task. The arithmetic task was a modified version of the three jars task. Participants were presented with a set of arithmetic problems each involving before a combination of jars having different capacities and were required to calculate a target volume of liquid by applying the formula "B–A–2C." In each problem, participants viewed images of three jars marked "A," "B," and "C" with numbers indicating their capacities, and a target vessel with a question mark indicating the volume of liquid that should be calculated. The capacities of the three jars and the required target volume varied across problems (see Table 2).

As in the demonstrated vulnerability group, participants were first presented with a "practice problem." Participants were allowed to start the task only if they were able to solve the "practice problem" (there was no time limit for this). Participants were given a maximum of two-and-a-half minutes to solve each problem. After typing a response (in the corresponding text box located underneath the picture illustrating the problem), participants could move from one problem to the next one by pressing a button. Following the completion of the arithmetic task, participants were required to read a text passage about counting techniques (see the Appendix S1).

After completing Session 1, all the participants moved to Session 2. For all groups, Session 2 included a computerized version of the alphabet maze task, adapted from studies by Cowen and Thomson (1951) and Heglin (1957). Participants viewed a series of 6 × 6 grids with each square of the grid containing a letter of the alphabet. For each grid, participants were required to identify a continuous and meaningful path of words by moving from the top-right corner to the bottom-left corner of the grid (words could run horizontally, vertically, or diagonally).

The task consisted of three sets of problems: (a) six "set problems," which could only be solved using the same long path through the maze (i.e., a ten-letter solution); (b) one "test problem," which could be solved via the previous long path but also via an alternative, shorter path (i.e., a six-letter solution); and (c) one "extinction problem," which could be solved only with the alternative shorter path (in this last case, the long path did not result in a meaningful phrase) (see Figure 1).

For each problem, participants were required to try to find the shortest solution (i.e., the one that used the fewest letters). As for the three jars and the arithmetic task, participants were first given a "practice problem" (see Figure 1). The "practice problem" consisted of an example grid that could be solved with a path that was different from those required to solve the three sets of previously described problems (to avoid participants applying the path that worked in the practice problem to solve the following problems). Participants were allowed to start the task only if they had been able to solve the "practice problem" (there was no time limit for this). During the task, participants were given a maximum of two-and-a-half minutes to find the solution for each problem. After typing a response (in the corresponding response bar located underneath the picture illustrating the problem), participants could move from one problem to the next one by pressing a button.

At the end of Session 2, all the participants were asked to answer some demographic questions, indicating their sex, age, level of education, and field of study. Participants in the demonstrated vulnerability group and in the asserted vulnerability group were also asked to provide the following information: (a) how often they thought they had previously experienced fixation (i.e., once per minute, once per hour, once per day, once per week, once per month, once per year); (b) an example of a real-life fixation episode that they had experienced (to ensure that they had correctly understood the concept of fixation and to link what they had learnt in the study to their everyday life); (c) state if they believed that knowing about their own (for the demonstrated vulnerability group) or other people's (for the asserted vulnerability group) vulnerability to fixation could have a positive effect on helping them to avoid fixation in the future. The total testing time

TABLE 2. Problems in the Arithmetic Task. For Each Problem, Participants were Asked to Calculate the Target by Applying the "B-A-2C" Formula

	Jar A	Jar B	Jar C	TARGET
Practice problem	11	65	8	?
Set problem 1	25	59	2	?
Set problem 2	32	69	3	?
Set problem 3	52	78	3	?
Set problem 4	43	93	4	?
Set problem 5	31	61	4	?
Test problem	13	35	3	?

Practice problem

N	E	V	E	S
D	P	M	L	X
O	G	K	Q	T
G	U	O	S	Z
S	E	Y	V	R

Set problem (1/5)

G	M	O	E	Y	L
Z	T	U	K	E	S
D	S	H	T	Q	E
A	V	C	J	H	F
B	W	F	Z	I	C
G	N	I	S	M	R

Test problem

I	O	B	C	L	H
M	N	T	Q	E	Z
H	G	F	R	Z	O
D	V	H	Y	R	J
X	A	G	Q	E	V
T	I	U	S	D	W

Extinction problem

P	A	Y	U	Y	H
R	W	L	S	I	Z
J	O	K	S	Z	V
U	B	H	Y	T	J
X	A	G	Q	O	V
T	I	U	S	N	C

FIGURE 1. Examples of problems used in the alphabet maze task. The solution for the "practice problem" required participants to follow the letters left, spelling “SEVEN," then down to spell "DOGS." The solution for the "set problem" required participants to follow the letters diagonally down to the left, spelling “LET,” step to the right and go down spelling "HIM," then go to the left spelling “SING.” The "test problems" offered two possible solutions: Participants could follow the same (long) path applied in the "set problem" or a shorter path using one diagonal run. In the example shown, the longer path spells “HER RED SUIT”; the shorter path spells “HER HAT.” The "extinction problem" could only be solved by applying the shorter path, spelling “HIS HAT.” In this case, applying the long path would lead to a meaningless phrase (“HIS TON SUIT”).

was about 40 minutes per participant (see Figure 2 for a summary of the activities completed by the participants in each group).

The participants’ behavior during the study was captured digitally, including (a) responses in the three jars task, in the arithmetic task, and in the alphabet maze task (in the form of the text entered by the participants in the response boxes); (b) the time spent on each problem before submitting a response (i.e., completion time), in the arithmetic task and in the alphabet maze task; (c) answers to the questions related to the "fixation" text (in the asserted vulnerability group); (d) demographic data; (e) answers to the follow-up questions; and (f) total time to complete the study.

RESULTS

Fifty-nine participants were removed from the analysis because they did not complete the activities properly (i.e., they were not allowed to complete one of the activities due to a failure in solving the "practice problems" or did not provide a valid response to all the problems within each activity). The final sample therefore consisted of 109 participants (i.e., 36 participants in the demonstrated vulnerability group, 35 participants in the asserted vulnerability group, and 38 participants in the control group).

As Session 1 was simply used to manipulate the participants’ knowledge of and experience of fixation (the independent variable), participants’ behavior was primarily analyzed in relation to their performance in

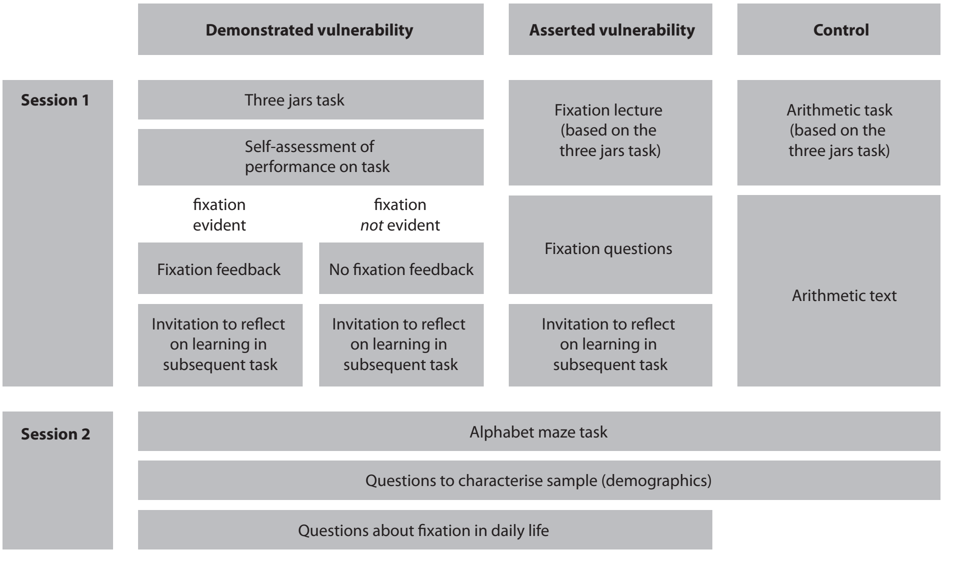

FIGURE 2. Tasks, activities, and follow-up questions completed by the participants in each group.

Session 2 (the dependent variable). However, to provide a baseline for the participants' susceptibility to fixation, we also report the proportion of participants in the demonstrated vulnerability group who exhibited fixation in the three jars task: 33 out of 36 participants (i.e., 91.67%) were persistent in applying the more complex (and previously used) arithmetic sequence to solve the "test problem."

Fixation in the alphabet maze task was quantified in terms of (a) persistence in applying the longer path to solve the "test problem," (b) inability to solve the "extinction problem," and (c) longer completion times on either the "test problem" or the "extinction problem" (compared with other participants).

The results revealed that more participants in the asserted vulnerability group (94.29%) and in the control group (92.10%) persisted in applying the long path that worked in the "set problems" to solve the "test problem" compared with the participants in the demonstrated vulnerability group (72.22%), $\chi^2(2) = 8.97$, $p = .01$, $\varphi = 0.29$ (see Figure 3). No significant difference was observed between the asserted vulnerability group and the control group, $\chi^2(1) = 0.14$, $p = .71$, $\varphi = 0.04$. This result was unaffected by removing those (three) participants who did not become fixated or those (two) who incorrectly evaluated their own performance[1].

All the participants (except 3 participants in the control group) attempted the "extinction problem." However, most participants failed to provide a meaningful solution (77 out of 109, or 70.64% of the participants; see Figure 3). There was no significant difference between the three groups in relation to the number of participants who failed to give a meaningful solution to the "extinction problem," $\chi^2(2) = 1.64$, $p = .44$, $\varphi = 0.12$ (see Figure 3).

Participants in the three groups did not significantly differ in relation to their completion times on the "test problem" (demonstrated vulnerability group: $M = 14.08$, $SD = 6.58$; asserted vulnerability group: $M = 21.27$, $SD = 21.47$; control group: $M = 17.54$, $SD = 10.13$), $F(2, 106) = 2.32$, $p = .10$, $\eta_p^2 = .04$ (see Figure 4). However, among those who were able to identify a meaningful solution to the "extinction problem" (33.33% of the participants in the demonstrated vulnerability group, 25.71% of the participants in the asserted vulnerability group, and 18.42% participants in the control group), participants in the demonstrated vulnerability group were significantly faster in correctly identifying that solution ($M = 10.88$,

[1] After removing those five participants, we still found that more participants in the asserted vulnerability group (94.26%) and in the control group (94.26%) persisted in applying the long path that worked in the "set problems" to solve the "test problem" compared with the participants in the demonstrated vulnerability group (76.47%), $\chi 2(2) = 7.12$, $p = .03$, $\varphi = 0.26$. No significant difference was observed between the asserted vulnerability group and the control group, $p = 1$.

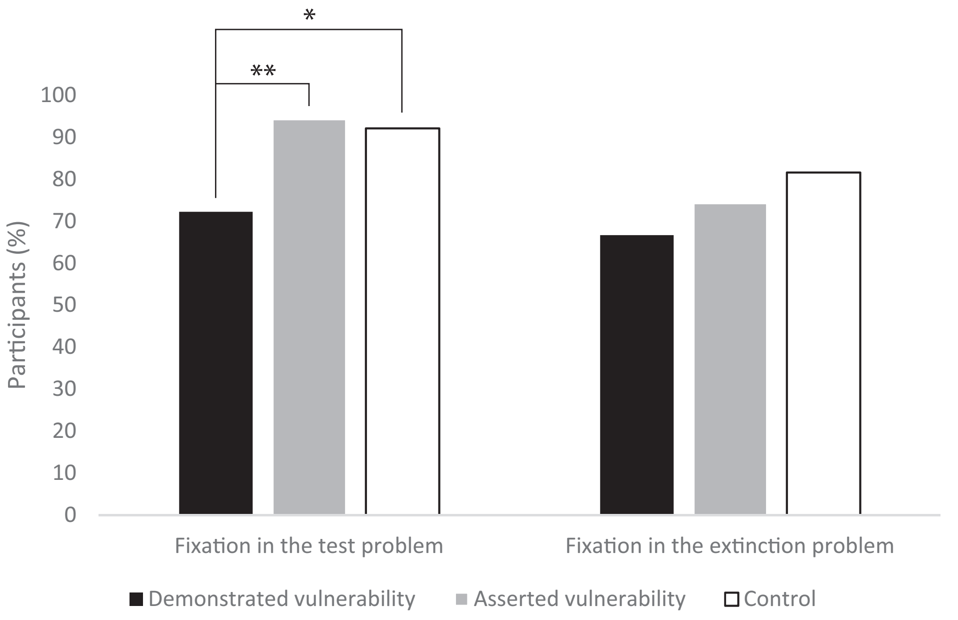

FIGURE 3. Proportion of participants in each group who persisted in applying the long path to solve the "test problem" and failed to identify a meaningful solution to the "extinction problem" (*$p < .05$; **$p < .01$).

$SD = 9.78$) compared with participants in the asserted vulnerability group ($M = 29.64$, $SD = 18.68$) and control group ($M = 29.41$, $SD = 27.65$), $F(2, 25) = 3.54$, $p = .04$, $\eta_p^2 = 0.22$. With respect to completion times, no significant difference was observed between the asserted vulnerability group and the control group, $t(14) = 0.02$, $p = .98$, $d = 0.009$ (see Figure 4).

The real-life examples of fixation provided by the participants also confirmed that those in both groups (demonstrated and asserted vulnerability) had correctly understood the fixation concept and the way in which it can manifest in everyday life. The participants' answers to the follow-up questions also revealed that those in the demonstrated vulnerability group and in the asserted vulnerability group did not differ in relation to their beliefs about the frequency that they experienced fixation in their lives (the most common answer in both groups was "once per day," 36.11 % of the responses in the demonstrated vulnerability group and 28.57% of the responses in the asserted vulnerability group), $\chi^2(2) = 5.57$, $p = .47$, $\varphi = 0.28$.

Finally, more participants in the demonstrated vulnerability group (34 out of 36, or 94.44%) believed that knowing about their own/other people's vulnerability to fixation could have a positive effect on helping them to avoid fixation in the future, compared with the participants in the asserted vulnerability group (22 out of 35, or 62.86%), $\chi^2(1) = 10.63$, $p = .001$, $\varphi = 0.39$.

DISCUSSION

Our study demonstrates that an effective way to improve creative problem-solving is to demonstrate people's individual vulnerability to fixation. The participants in the demonstrated vulnerability group outperformed those in the asserted vulnerability group and those in the control group. This supported our hypothesis that providing people with experiences that demonstrate their individual vulnerability would give rise to a significantly stronger tendency to resist later fixation episodes than simply asserting that people in general are vulnerable to fixation. More specifically, our demonstrated vulnerability group were less persistent in applying the longer path to solve the "test problem" and were quicker to solve the "extinction problem." We also predicted that the asserted vulnerability group would be less fixated than the control group (who had not previously received any intervention related to fixation), but this was not what we found. The

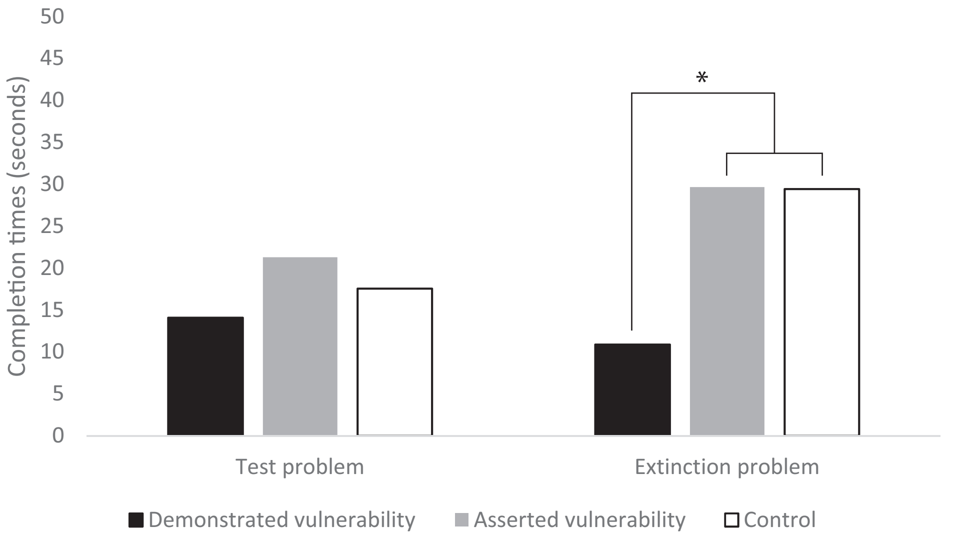

FIGURE 4. Average completion times for each group on the "test problem" and the "extinction problem" (*$p < .05$).

asserted vulnerability group did not outperform the control group, only the demonstrated vulnerability group did. We see at least four possible explanations for these findings, each of which are related.

First, experiencing fixation increased people's awareness of their own vulnerability to the risk and this awareness allowed them to change their behavior. This corresponds with the findings from Sagarin et al.'s (2002) third experiment, where those made aware of their own vulnerability to persuasion were better able to resist later persuasion attempts. This awareness can be seen as a challenge to the optimistic bias (see Aiken et al., 2001; Weinstein, 1980), fitting with Curry et al.'s (1993) findings that providing tailored personal objective risk information increased cancer screening among higher risk women. In our study, this explanation could only apply to those participants who underwent the demonstrated vulnerability treatment who did indeed exhibit fixated behavior, which was the majority. For those few who did not exhibit fixated behavior, their improved performance might be attributed to their possible increased self-efficacy as they received positive feedback in the form of a "good job" message (Schunk, 1991; Tierney & Farmer, 2011). In this way, a demonstrated vulnerability treatment in the form we implemented it might elevate the performance of the majority who become fixated and also the minority do not.

Second, the improved performance of the demonstrated vulnerability group can be associated with the positive effect of critical feedback on later performance. The participants who exhibited fixated behavior were provided with new information about their own behavior: Their lack of flexibility had caused them to perform in a suboptimal way. Prior experimental research indicates that feedback is a valuable way of improving creative performance (Carson & Carson, 1993), and fieldwork indicates that feedback from others can be an effective challenge to design fixation (Crilly, 2015). Although in the first session, we ostensibly provide new information to both the demonstrated and asserted vulnerability groups, the asserted vulnerability group might plausibly be receiving information that they already have but just in a different form. Studying the effect of cognitive feedback in improving performance, Youmans and Stone (2005, p. 339) conclude that it is important to understand what information participants have before and after an intervention. Participants in many studies might know what the task is and what good and poor performance would look like. What they do not know is whether they are likely to exhibit good or poor performance. As such, the demonstrated vulnerability intervention actually adds new information in a way that warnings of fixation might not.

Third, the demonstrated vulnerability group's personal involvement in the task might have made those participants more alert to the possible risk of fixation in the alphabet maze task. Their creative metacognition might have been enhanced through engagement rather than through feedback. This is related to Jacoby and Kelley's (1987) demonstration that people's judgments about the relative difficulty of anagrams were much less accurate when those judgements were made with the solution available (e.g., "FSCAR-SCARF") than when made after having the experience of solving the anagram. When they had solved the anagrams themselves, they underestimated the difficulty (for similar results, also see Kelley & Jacoby, 1996). In relation to that, Storm and Hickman (2015) argued that even if people are aware of the effects of fixation in some overall sense, such awareness may not necessarily inform predictions regarding the ability to solve specific problems.

Fourth, personal involvement in the task may have increased the demonstrated vulnerability group's memory for the "fixation" lesson they received, so that that lesson was more effective in the later task. Related to this is evidence that personal experiences may be processed differently or more thoroughly, making them easier to recall and having a greater influence on subsequent behavior (e.g., Borgida & Nisbett, 1977; Kahneman & Tversky, 1973; Nisbett et al., 1976). The recollection of events that are referenced to "the self" has been shown as superior to the recollection of events lacking such self-reference (e.g., Brown, Keenan, & Potts, 1986). This might account for the ineffective use of warnings in our study and the mixed results that warnings have had in prior work.

While the effectiveness of demonstrating vulnerability to fixation has not previously been shown in experimental studies, it does fit with previous qualitative research reporting that creative professionals recognize previous fixation episodes and reflect on those in future work to reduce the occurrence and influence of fixation (Crilly, 2015). For example, one expert designer said "The more projects you do then the more you ⋯ self-analyse⋯. I think if you do that [analysis] every time, eventually when you start another project you go: 'Oh, I remember doing that [fixating] last time and at the end I had all these other solutions. Maybe we should just check to make sure that there aren't some more solutions there'. So I suppose it's something that comes with experience" (p. 75). Our research objective here has been to explore how such experiences and self-analysis might be accelerated. We find that a demonstrated vulnerability intervention is an effective approach.

Our use of a computer-based task to measure fixation is an approach that brings a number of methodological benefits (for the discussion, see Neroni, Vasconcelos & Crilly, 2017). Among these benefits, there is the possibility to record how much time participants spent on each problem before submitting a response (what we referred to as "completion time"). In our study, recording completion times in the alphabet maze task allowed us to exclude the possibility that participants in both the asserted vulnerability group and in the control group were less able to identify the "best" (i.e., simpler) solution to the "test problem" simply because they spent less time on this problem compared with the participants in the demonstrated vulnerability group. Recording completion times also gave us an additional, complementary measure of the effect of experiencing fixation on later performance. In particular, we did not find a significant difference between the three groups with respect to the participants' ability to identify a meaningful (and shorter) solution for the "extinction problem." This was due to an increased number of participants in the asserted vulnerability group and in the control group who were able to find the shorter solution for the "extinction problem" (compared with those who were able to find it when solving the "critical" problem). This is in line with previous research showing that fixation on a suboptimal solution can be reduced when that solution is simply not available (e.g., Luchins, 1942; Ransopher & Thompson, 1991).

However, among those who were able to identify a meaningful solution to the "extinction problem," participants in the demonstrated vulnerability group were faster compared with those in the asserted vulnerability group and in the control group. This reveals an additional effect of fixation on problem-solving: a need for more time to solve problems (Bilalić, McLeod & Gobet, 2008). This effect cannot be simply attributed to the demonstrated vulnerability group's previous experience with a time-limited task. If this was the case, we would have found faster completion times in the control group too (as this group had previously completed a similar time-limited task), but we did not.

Computer-based tasks also provide a basis for considering how a demonstrated vulnerability treatment might be implemented in real-life contexts of creative training or development. In considering computational support for creative education, Burleson (2005) reports that "Through simulated Learning By Doing environments, it is possible to accelerate the pace of learning through exposure to difficult circumstances [⋯]. This will inevitably accelerate the rate of failure and, if motivation is sustained, the rate of learning as well" (p. 445). Such interventions can have lasting effects, especially if they demonstrate that individuals have the potential to improve their abilities (Yeager & Walton, 2011). With this in mind, our demonstrated vulnerability treatment might be developed further by telling participants that they succeeded in improving their performance. A more effective intervention might therefore involve four stages: initial creative task (e.g., three jars task), demonstrated vulnerability feedback, subsequent creative task (e.g., letter maze task), and performance improvement feedback.

Despite the clear results, our study has a number of limitations, which should be considered when generalizing to other settings or planning future work. We used two brief closed-ended tasks in quick succession, both of which provided objective measures of solution quality (number of arithmetic operations; number of letters used). This permitted participants to identify their own fixated behavior in the first task (demonstrated vulnerability group) and for us to measure such behavior in the subsequent task (demonstrated and asserted vulnerability groups). While this setup was methodologically convenient, we might question whether the same results could be obtained for more complex, time-consuming and open-ended tasks. Many studies of creative fixations use tasks that take an hour or more, where there is no right or wrong answer and where numerous objectives might be in conflict with each other (for an analysis, see Vasconcelos & Crilly, 2016). However, it has not been demonstrated whether the ways in which we might improve performance on those tasks is different from the ways in which we might improve performance on other tasks that permit more objective measures and therefore more reliable claims that fixation was indeed present (for an evidence that solving closed simple problems relies on similar cognitive processes to the solving of open complex ones, see Hay et al., 2019; but also see Jausovec, 1997). Here, we prioritized experimental control over task complexity, but the validity of those more open-ended tasks conducted in laboratory conditions has not been demonstrated in any case (Crilly, 2019). Useful future work could establish whether the phenomena of interest vary with task complexity and whether this affects our ability to generalize our findings about demonstrated vulnerability to real-world contexts.

We might also question whether our study would achieve the same results with a substantial time delay between the two tasks. Going further, would a single demonstrated vulnerability intervention improve creative performance for a series of activities during a project or career, and if so, what form of intervention would be required? The professional experiences that Crilly's (2015) professional designers were reflecting on were projects in which the consequences of fixation were more problematic than just using too many mathematical operations or letter choices in a puzzle game. They were reflecting on more consequential errors, such as the development of inferior technical solutions, substantial project delays, or additional unpaid work. Such experiences, especially if repeated, might be expected to have an impact on the person's sense of self and therefore have more long-lasting effects. Although in our study, the participants in the demonstrated vulnerability group reported that they believed that a positive effect would be long-lasting (more than in the asserted vulnerability group), we still do not know what kind of intervention would really be required for that to be achieved. Still, there is some evidence that more general creativity training can have long-lasting effects (see review in Scott, Leritz, & Mumford, 2004: p. 375) and so there is some potential for a demonstrated vulnerability improvement to be persistent.

One alternative interpretation of our results is that the participants in the demonstrated vulnerability group simply understood the concept of fixation better because they more fully engaged with the three jars task than those in the asserted vulnerability group. We tried to guard against this by requiring our asserted vulnerability group to correctly answer a series of questions about fixation. This seemed to be effective as we found no difference in how the two groups understood fixation, either in terms of the types of examples they gave or in terms of their estimated frequency of its occurrence in daily life. In any case, our result could plausibly have been reversed because we required our demonstrated vulnerability group to self-evaluate and they then received critical feedback on their behavior. Such actions have been shown to impair creativity, perhaps by lowering confidence and directing attention to the self rather than the task (see review and study in Szymanski & Harkins, 1992). However, such impairment might not occur if the self-evaluation leads people to believe that they have the possibility to improve their performance in the future (Silvia & Phillips, 2004). That appears to have been the case here.

CONCLUSION

Previous efforts to reduce fixation effects have often involved providing people with training or warnings about fixation and encouraged them to guard against exhibiting fixation in later tasks. There are at least three interrelated reasons to suspect that these approaches might be ineffective and why demonstrated vulnerability may be more effective. First, people underestimate or discount their own individual susceptibility to risk. Second, people consider that others are more susceptible to bias than they are themselves. Third, people learn better if they are given opportunities to have meaningful personal experiences and then reflect on those. These three factors might all account for the efficacy of the demonstrated vulnerability treatment in Sagarin et al.'s (2002) third experiment, a treatment that we modified here to make it applicable to fixation rather than persuasion.

In an effort to reduce fixation effects, we have mostly focused on a comparison between demonstrating vulnerability (through experience) and asserting vulnerability (through warnings). However, there is another popular approach: providing creative tools and techniques. Our results are relevant to this approach also because such tools and techniques might be more effective if combined with demonstrating individual vulnerability to fixation. If we are interested in reducing the effects of people's biases in creative activities, then we should account for the biases that they might have toward such biases. We should understand that they might underestimate the degree to which creative tools and techniques are relevant to their own abilities and practices. We have shown that demonstrating individual vulnerability to fixation can improve performance in subsequent tasks. It might also improve engagement with creative tools and techniques, leading to their more effective application. The best interventions could lie in a combination of multiple approaches, with a demonstration of individual vulnerability to fixation motivating people to guard against it with whatever means are available to them.

DATA SUPPORTING

Research data supporting this publication are available from the University of Cambridge data repository at: https://doi.org/10.17863/CAM.44361

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AUTHOR NOTE

Conflict of interest: The authors declare that there is no conflict of interest.
Funding: This work was supported by the UK's Engineering and Physical Sciences Research Council (EP/K008196/1).

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Appendix S1. Full instructions and materials used in all the tasks.